# Autonomous Intelligent Drone Swarms for Signal Quality Measurement

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**Summary**

Decrease in signal strength and quality poses a significant risk to the reputation and bottom line for 4G/5G wireless telephony and Wi-Fi service providers. Lower data rates and frequent outages are a direct result of common and preventable issues with poor signal quality.

Existing signal quality measurement methods are slow, expensive, and impractical for some physical environments such as urban high-density areas and transport corridors.

A solution based on an autonomous swarm of micro aerial vehicles equipped with communication measurement devices and artificial intelligence can perform the signal quality measurement task more reliably, efficiently, and with greater agility in access to remote areas than existing methods.

**Signal Quality Measurement**

Signal strength and signal quality are key performance indicators measured in communications systems such as 4G/5G mobile telephony and Wi-Fi networks. Understanding the level of these indicators is critical for a successful deployment and operation of communication infrastructure. High customer expectations of service quality require a diligent approach when it comes to these parameters.

In mobile telephony and wireless networks, customers perceive service quality primarily through first-hand experience with data rates and service outages. Frequent dropped calls or low bandwidth give impression of poor quality and lead to bad reputation for service providers.

Service quality is a direct result of how well engineered the communication network is. Signal strength and quality, in addition to capacity planning, are the primary considerations in the engineering of a communication network.

*Signal Strength and Quality Indicators*

There are four main signal strength and quality indicators used in wireless communication:

a) RSSI
b) RSRP
c) RSRQ
d) SINR

Received Signal Strength Indicator (RSSI) is a measurement of the overall power in the received signal across the entire band and includes interference and noise signals. Expressed in decibels relative to milliwatt (dBm), it ranges from 0dBm on the optimal side, to -100 dBm and below on the poor side. Typically, any RSSI above -50dBm is considered good quality.

Reference Signal Received Power (RSRP) is another signal strength indicator and corresponds to the average power of the reference signal blocks, i.e., the useful part of the transmission. Typically, values above -80dBm are considered excellent quality, while values below -100dBm can result in dropped connections.

Unlike the previous two, Reference Signal Received Quality (RSRQ) indicator measures the quality of the signal. Based on the portion of the useful signal power to the overall power in the received signal, it accounts for the presence of interference and noise. Values above -10dB indicate excellent quality with maximum data speeds, while values below -20dB may result in disconnection.

Similarly, Signal to Interference plus Noise Ratio (SINR) measures the signal quality and is a direct indicator of the maximum data throughput.

### *Important Factors That Affect Signal Quality*

There are many factors that can affect signal strength and quality. First, there is the obvious – the design and engineering of the transmission antenna and tower. Key considerations in planning and development of communication infrastructure include capacity, i.e., the number of customer devices that affect tower load, presence of other communication networks in the same area that may cause interference, and the characteristics of the terrain and physical surrounding.

Signal interference is one of the main challenges for good signal quality. Sources of interference include other communication networks transmitting in the same area and on similar frequencies, but also radiation from other electrical devices and undesired reflection effects.

Other important factors affecting signal strength and quality include proximity to the antenna tower, physical barriers, natural or manmade, construction materials used, and even weather. It's not uncommon to experience signal degradation around steel and concrete high-rise buildings in high-density urban areas, both at ground level and high above ground. In rural areas, on the other hand, the key factor is distance, as each cell tower has a specific range.

### *Impacts of Decrease in Signal Quality*

Signal quality degradation can occur during all phases in the development lifecycle of the communication network. This is why simply planning and development of the system is insufficient to maintain excellent quality of service. The environment in which the network operates evolves over time and with it the factors that affect signal quality. Periodic signal strength and quality monitoring is necessary to prevent outages and the negative impact to service providers' reputation before they occur.

Changes such as newly constructed buildings and infrastructure, increase in traffic or population in an area, or deployment of new networks may all lead to a permanent decrease in signal quality. On the other hand, intermittent factors such as construction projects, weather patterns, or large events may require temporary solutions to boost the strength and quality of the communication network.

Communication service providers need to implement solutions to remedy signal quality issues, such as installing signal repeaters, or upgrading towers. Without a complete signal strength and quality map, it is difficult to plan and deploy these solutions in a way that effectively solves the signal issues.

Besides a direct impact on the costs of operations to remedy the issues with signal strength, repeated challenges with poor signal quality may lead to a loss of customers with a detrimental impact on the service provider's bottom line.

### *Existing Measurement Methods*

Signal strength and quality measurement requires the physical presence of a measuring device, i.e., a radio receiver, at the precise location of measurement. Electrical signals from the device are captured and analyzed with signal processing hardware to determine the values of key performance indicators, such as RSRP and RSRQ.

There are two general categories of measurement devices:

a) commercial signal measurement software that runs on off-the-shelf mobile phones and tablets with wireless connectivity; and
b) specialized integrated communication devices that contain both the hardware and data capture and analysis software.

In both cases, measurement operations typically include field personnel physically traversing the designated area on foot or by vehicle and operating the device to capture the signal data. The data is later stored and analyzed to identify zones with decreased signal strength and infer other insights about signal quality.

**Challenges with Existing Methods**

Existing signal quality measurement methods face several important challenges.

Field operations that involve workers physically visiting and fully and diligently covering the site to map the signal indicators are slow, inefficient, and expensive. Particularly when it comes to covering a large area, and especially areas that are difficult to reach such as those around transit corridors. Additionally, some environments are hazardous for human workers and would result in gaps in the captured signal quality data.

In some cases, such as around high-rise buildings, communication towers, or tall physical barriers, getting an accurate and complete picture of the impact of the physical environment on signal quality requires building three-dimensional measurement maps. Obviously, getting measurements at high altitudes above ground requires specialized and expensive equipment and is often not possible without the use of aircrafts.

Given the need for field personnel, specialized equipment, and a slow measurement process, field operations are typically performed with a lot of pre-planning and designed to be as expedient as possible, and thus with very little opportunity to adapt in real-time to the insights gathered from captured signal measurement data. High cost makes repeated operations impractical, often resulting in an outdated view of the signal quality.

**Novel Approach Based on Intelligent Drone Swarms**

An intelligent drone swam is a system of independent but coordinating unmanned aerial vehicles (UAVs) that collectively perform a surveying mission.

Each drone in the fleet is typically equipped with one or more sensors, in this case with a signal measurement device. The device onboard the drone receives wireless communication, measures the signal strength and quality, and captures and transmits the data to the Cloud.

In addition to the ability to capture the data and transmit to the Cloud, drones are equipped with artificial intelligence capabilities, enabling them to make real-time decisions based on insights from the captured data, and adapt to their environment.

For the most part, autonomous drone swarms don't require a human operator since the intelligence capabilities enable them to maneuver the physical environment safely and precisely while they perform data capture.

Types of drones commonly used for these applications include enterprise drone platforms such as DJI Mavic 3 Enterprise, and DJI Matrice 350. These are high-end enterprise drones used for commercial and industrial applications.

*Typical Use Cases*

Some typical use cases for signal strength and quality measurement using autonomous intelligent drone swarms include:

a) measuring 4G signal quality along the railway and road transit corridors to determine the optimal location for new tower development
b) measuring 4G signal quality around new high-rise construction to estimate the impact on signal degradation from new buildings and plan repeater deployment

c) building a three-dimensional signal quality map around transmission towers to assess the impacts of interference and physical barriers.

**Benefits of the New Approach**

A signal measurement solution based on an autonomous swarm of micro aerial vehicles equipped with communication measurement devices and artificial intelligence has several advantages over existing methods.

A drone swarm can perform the measurement task faster, as drones are able to move around the space horizontally, vertically, above and around obstacles with far greater agility, reaching inaccessible terrain far more easily than human workers. A swarm of five to ten drones can cover a large area in less time and more efficiently, as the drones coordinate to optimally cover the space.

Drones can be an effective solution for above ground measurements as well, avoiding the need to invest in expensive equipment or larger aircrafts, further reducing the costs of field operations.

At the same time, multiple drones can perform repeated and more reliable measurements, tolerant to intermittent changes. An increase in redundancy and reliability of measurement yields better operational results.

Finally, the benefits of real-time operational decisioning supported by artificial intelligence applied to drone-collected signal measurement data are massive. Rather than having to perform multiple surveys, drones can identify the problem areas and autonomously adjust the focus of their operation without the need for manual intervention.

**Risks**

There are two main risks to adopting the drone-based approach in signal measurement operations.

First, the novel technology requires an investment in equipment and people / skills. Leading-edge technology solutions, often viewed as too experimental, are difficult to adopt by organizations that don’t have an innovation culture. Successful adoption requires not just financial investment and training, but potentially operating model changes, and certainly changes in standard operating procedures. Companies that are best able to absorb this type of innovation are those that continuously innovate their operations to remain competitive.

The second major risk is regulatory. Drone operations are regulated in most countries. Mandatory compliance with drone regulations, even in commercial and industrial use, includes appropriate registrations, licenses, and approvals from the overseeing body, particularly when operating in high density urban areas or near critical infrastructure. A lackluster approach to regulatory compliance could lead to fines or reputational risk for service providers.

With proper care and a strategic approach, the risks are manageable. The opportunity for communication service providers is significant. The potential for cost savings in signal measurement operations is sizeable. The upside from improved service quality – far greater. ■

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